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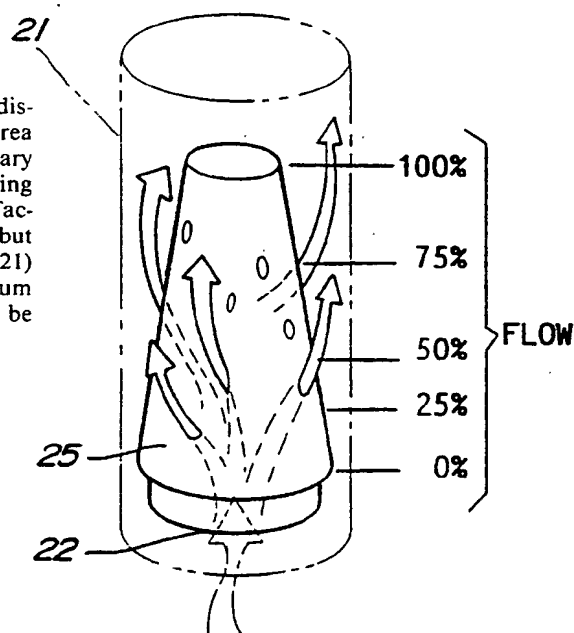
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B01D 29/88	A1	(11) International Publication Number: WO 94/05396 (43) International Publication Date: 17 March 1994 (17.03.94)
(21) International Application Number: PCT/US92/07383 (22) International Filing Date: 31 August 1992 (31.08.92) (71) Applicant (for all designated States except US): POROUS MEDIA CORPORATION [US/US]; 1350 Hammond Road, St. Paul, MN 55110 (US). (72) Inventor; and (75) Inventor/Applicant (for US only) : SPEARMAN, Michael, R. [US/US]; 4311 Pondview Drive, St. Paul, MN 55110 (US). (74) Agent: DOLGORUKOV, D., Edward; Marshall & Melhorn, Four SeaGate, Eighth Floor, Toledo, OH 43604 (US). (81) Designated States: AU, BR, CA, JP, KR, KZ, NO, RU, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, SE).		Published <i>With international search report.</i>

(54) Title: CONICAL COALESCING FILTER

(57) Abstract

A porous coalescing filter element (25) of conical configuration is disposed within a substantially cylindrical filter housing (21) such that the area between the element and the wall increases in the direction of the primary phase flow to keep the annular velocity substantially constant or decreasing in the direction of primary fluid flow. The element (25) may be manufactured with a round end and tapered walls terminating to a pointed apex, but is more preferably manufactured and secured within the filter housing (21) using flat end caps on both ends. The filter element (25) may be vacuum formed, or manufactured from media in a flat sheet form, which may be pleated if desired.



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TITLE

CONICAL COALESCING FILTER

BACKGROUND OF THE INVENTION

5

Field of the Invention.

The present invention relates to the coalescing art, and specifically to an improved coalescing filter element which may be used in virtually any coalescing filter
10 assembly. More particularly, the invention relates to a coalescing filter element used in separating liquid droplets from gases or other liquids, and having a conical configuration. The conical configuration allows for lower velocity of the primary phase fluid in the area between
15 the outside surface of the coalescing element or elements and the filter assembly inner wall, thereby reducing the maximum droplet diameter which may be supported by or reentrained in the primary phase fluid. This allows for more efficient separation of the coalesced droplets from
20 the primary phase fluid. It also allows for lower pressure drop through the coalescing filter elements.

Description of the Prior Art.

The need to separate liquid droplets from gases or
25 other liquids is long standing in the art. Common liquids found in air and gas streams include lube oils, water, salt water, acids, caustics, hydrocarbons, completion fluids, glycol and amine. The liquid normally is present in the form of tiny droplets, or aerosols. The size
30 distribution of the aerosols is primarily dependent on the surface tension of the liquid contaminant and the process from which they are generated. As the surface tension is reduced, the size of the aerosol is reduced accordingly. This is because the intermolecular cohesive forces (the

forces which attract the surface molecules of an aerosol inward in order to minimize surface area with respect to volume) are weaker.

It has been found that greater than 50% of all oil aerosols by weight are less than 1 micrometer in diameter. Due to their similar surface tensions, the same holds true for glycols, amines and hydrocarbons. Conventional filtration/separation equipment such as settling chambers, wire mesh (impingement) separators, centrifugal or vane (mechanical) separators and coarse glass or cellulose filters are only marginally efficient at 1 micrometer, and remove virtually none of the prevalent sub-micrometer aerosols and particles. In order to remove these problem-causing contaminants, high efficiency coalescing filters must be used.

All previous coalescing filters and coalescing elements of the type with which the present invention is concerned are configured in a tubular or cylindrical arrangement, and used to flow in to out or, from out to in. While it is advantageous to flow from out to in for many filter applications, there is also a definite advantage for flowing in to out for the coalescing of liquid droplets and aerosols from gases, or the coalescing of two immiscible liquid phases.

In these applications, it is common to use coalescing elements secured within a pressure-containing vessel or housing to form a coalescing filter assembly. The continuous phase gas or liquid contains dispersed liquid aerosol droplets, sometimes referred to as the discontinuous phase. The mixture enters the assembly through an inlet connection and then flows to the inside of the coalescing element. As the fluid flows through the

filter media of the coalescing element, the liquid droplets come in contact with the fibers in the media and are removed from the fluid stream. Within the media, the droplets coalesce with other droplets and grow to emerge
5 as large droplets on the downstream surface of the element which are capable of being gravitationally separated from the continuous phase fluid. If the density of the droplets is greater than that of the fluid, such as oil droplets in air, the droplets will settle gravitationally
10 to the bottom of the filter assembly, countercurrent to the upward flow of air. If the density of the droplets is less than that of the fluid, such as oil droplets in water, the droplets will rise to the top of the assembly countercurrent to the downward flow of the water.

15 The droplet size, droplet density, fluid viscosity, and fluid density will determine how rapidly the droplet settles or rises in the filter assembly. It is advantageous in designing coalescing filter assemblies to try to maximize the flow rate of the fluid through the
20 assembly while not reducing separation efficiencies in order to reduce the size of the housing required for a given flow rate, and thereby reduce the manufacturing costs.

25 However, the cylindrical coalescing elements of the prior art impose substantial limiting factors in designing filter housings. The cylindrical configuration of the coalescing elements provides a fixed annular space between the element and the housing wall. Therefore, assuming substantially even flow distribution across the surface of
30 the coalescing element, the annular velocity increases linearly from the bottom to the top of the element.

With the cylindrical element design, the annular velocity will be different at all points along the axial length of the element. For example, in separating oil droplets from a gas, the gas will flow upward upon exiting the element, and the liquid droplets will settle downward. At the bottom of the element there would be no flow, so the annular velocity would be zero. At the top of the element, all of the gases would have exited the element and be flowing upward. The annular velocity would be 100% of the flow divided by the cross sectional open area (the area between the element and the vessel wall). Similarly, at a point in the middle of the element the annular velocity would be 50% of the total flow divided by the cross sectional open area. Great care must be taken not to exceed the annular velocity which will cause reentrainment of the droplets.

Furthermore, the pressure drop which results from the gas entering the open end of the element is a function of the inside diameter of the element. The inside diameter of cylindrical elements is limited by the diameter of the housing, the thickness of the wall of the element, and the size of the annular space. It is necessary to maintain sufficiently low annular velocities so as not to reentrain liquid droplets. The smaller the inside diameter is, the higher the pressure drop will be for a given flow rate.

After much study of the problem of how to reduce the annular velocity to prevent reentrainment of the liquid droplets, a substantially conically shaped coalescing filter was devised wherein the open area between the wall of the housing and the filter element increases in the direction of flow. The annular velocity can be expressed as $V_a = Q/A_x$ where Q is the flow and A is the open cross

sectional area. It can be seen that if the area between the filter element and the housing increases as the flow increases, the annular velocity may be made to remain constant or, if desired, even to decrease.

5 Once the idea of a conical coalescing filter was developed, a search of the prior art in the United States Patent and Trademark Office was made to determine if this was new. The only patent located which discloses a
10 conical coalescing element is U.S. Patent No. 2,823,760 to S. K. Anderson entitled "Water Separator". Other patents were located during the search, but were not relevant. Upon close study of the Anderson "Water Separator", there was found to be a similarity in appearance only. Anderson
15 deals with maintaining a constant pressure. It is not an in to out coalescer, and in fact is a centrifugal coalescer which flows out-to-in and relies on centrifugal force and subsequent steady flow rate to separate the
20 coalesced droplets from the primary phase fluid. Thus even though Anderson thought of making a conically shaped coalescing filter cartridge, he did so for an entirely
25 different purpose, and did not solve the problems in the coalescing filter art which Applicant addresses.

SUMMARY OF THE INVENTION

25

 The present invention solves the problem in the prior art by providing a conical coalescing filter element which may be used in virtually any coalescing filter assembly, depending on the application, to separate liquid drops
30 from gases or other liquids. Such a configuration allows for lower velocities of the primary phase fluid in the area between the outside surface of the coalescing

elements and the filter assembly inner wall, thereby preventing reentrainment of the coalesced liquid back into the air stream.

In a preferred embodiment of the present invention, a
5 conical element is disposed in a common T-type filter housing with its smaller end being in communication with the inlet of the filter housing for coalescing oil from air. The same conical filter element may be used in a multiple element housing wherein the flow enters the
10 bottom, or wide part, of the element. In both embodiments, the flow proceeds from in to out, and the annular velocity between the filter element and the wall of the filter housing will be substantially constant. Depending on the particular application, other
15 configurations may be provided so long as the smallest end of the conical filter is pointed toward the direction of the primary phase flow. The media used in the filter element can be vacuum formed, pleated or wrapped, and the conical coalescing element of the present invention can be
20 used to separate liquids from gas, or one liquid from another liquid.

Thus, it is an object of the present invention to provide a coalescing filter element and coalescing filter assembly which will provide lower annular velocities in
25 the same size vessel than cylindrical elements of similar flow ratings.

It is a further object of the present invention to provide a coalescing filter element and coalescing filter assembly wherein the annular velocity remains
30 substantially constant at all points along the axial length of the element.

It is a further object of the present invention to provide a coalescing element and coalescing filter assembly wherein the annular velocity may decrease as the flow travels from the bottom to the top of the filter element.

A still further object of the present invention is to provide a coalescing element and coalescing filter assembly which will provide lower overall pressure drop through the coalescing filter assembly.

A still further object of the invention is to provide a means for reducing or minimizing the size of the coalescing element and the coalescing filter assembly for a given flow rate and pressure drop.

Further objects and advantages of the present invention will be apparent from the following description and appendix claims, reference being made to the accompanying drawings forming a part of the specification, wherein like reference characters designate corresponding parts in the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagrammatic view of a prior art cylindrical coalescing cartridge mounted in a cylindrical filter housing.

Fig. 2 is a diagrammatic view of the conical coalescing filter of the present invention mounted in a cylindrical filter housing.

Fig. 3 is an elevational view, partly in section of a T-type filter housing showing the conical coalescing filter of the present invention between end caps in a cylindrical housing.

Fig. 4 is an elevational view, partly in section of a multiple element, high efficiency, coalescing filter.

Fig. 5 is a sectional view, taken in the direction of the arrows, along the section line 5-5 of Fig. 4.

5 It is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other
10 embodiments, and of being practiced or carried out in various ways within the scope of the claims. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and not of limitation.

15 DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is advantageous in designing coalescing filter assemblies to try and maximize the flow rate of the fluids in the assembly, while not reducing separation
20 efficiencies, in order to reduce the size of the housing required for a given flow rate and reduce the manufacturing cost. In doing so there are three important considerations:

- 1) The face velocity across the filter media.
 - 25 2) The annular velocity of the continuous phase fluid.
 - 3) The pressure drop across the coalescing filter assembly.
- 30 The effect of face velocity upon filter performance will be governed by the fact that as face velocity increases, filter efficiency is reduced. In addition, higher face

velocities will also cause higher pressure drops across the filter media and element.

As the dispersed droplets are captured by the fibers within the filter media, the rate at which they move
5 toward the downstream surface is a function of the drag force of the continuous phase flowing through the media on the droplets. When the drag force exerted on the droplet exceeds the force of adhesion of the droplet to the fiber, the droplet will become reentrained in the fluid. The
10 drag force is a function of the viscosity and velocity of the continuous phase fluid, and the size of the droplet, while the force of adhesion is a function of the interfacial surface tension between the droplet and the fiber.

15 Another objective in the design of coalescing filters is to create as large droplets as possible so as to assure they settle (or rise) and are not reentrained in the fluid flow. As the face velocity of the continuous phase liquid increases, the drag force increases. The increased drag
20 force is capable of shearing small droplets from the fibers. After the fluid flows through the coalescing filter element, it flows between the outer surface of the element and the inner wall of the vessel. The rate at which the fluid flows within the annular space between the
25 element and housing wall is called the annular velocity. If the annular velocity of the fluid is greater than the settling velocity of the droplets, the droplet will not settle and will remain entrained in the fluid.

Further, it is advantageous to minimize the pressure
30 drop across the filter assembly. The pressure drop, or pressure loss, is primarily caused by the restriction of the flow through the filter media, and the restriction of

the flow through the open end of the element as the fluid enters the inside of the element. The pressure drop through the filter assembly is the sum of the pressure drop through the housing and the coalescing element. The pressure drop through the element is dependent upon the permeability of the media and the surface area. The pressure drop through the housing is largely caused by the restriction of the inlet and outlet connections and the opening or restriction to the inside of the element. In designing the conical coalescing filter element of the present invention, the filter designer will need to take the above facts into consideration.

The annular velocity may be expressed as $V_a = Q/A_x$, where Q is the flow rate and A is the annular area between the filter element and the wall of the filter assembly. It should be understood that this is an approximate formula. Designing a filter element wherein the velocity was exactly constant along the linear length of the filter would result in a filter having of slightly parabolic shape. While this is well within the scope of the present invention, it is not the preferred embodiment.

After the designer has decided all of the above parameters, the conical coalescing filter elements of the present invention may be manufactured in similar ways as the coalescing filters of the prior art. Such coalescing filters may have one or more support cores, support layers, end caps and elastomeric seals. The media may be manufactured into an seamless tube by applying a vacuum to the inside of a porous mandrel and submersing the mandrel in a slurry of fibers of various compositions as seen in U.S. patent No. 4,836,931 to Spearman and U.S. patent No. 4,052,316 to Berger.

It is also possible that the conical filter may be manufactured from media in a flat sheet form and rolled several times around a center core like devices seen in U.S. patent No. 3,802,160 to Foltz, U.S. patent No.

5 4,157,968 to Kronsbein, or U.S. patent No. 3,708,965 to Dominik.

The media may be manufactured in flat sheet form and rolled several times around a cylindrical mandrel, impregnated with a resin binder to offer rigidity, and the
10 mandrel removed as seen in U.S. patent Nos. 4,006,054, and 4,102,785 to Head and U.S. patent No. 4,376,675 to Perotta.

The filter media may also be pleated. Pleating is well known in the art.

15 Advantages of the conical coalescing element can be best illustrated by comparing it to other conventional cylindrical coalescing elements. The following examples compare cylindrical elements of two sizes (2.75" OD x 30" L and 6" OD x 36" L) with conical coalescing elements
20 which fit in a filter vessel with the same inside diameter with the respective cylindrical element. In both examples, the fluid used is natural gas at 1,000 psig and 60°F.

25 Example 1

In a given filter vessel diameter, the improved conical coalescing filter element provides lower annular velocities and lower pressure drops than conventional cylindrical elements. In Example 1, conical elements are
30 compared with cylindrical elements at the same flow rates through the comparative elements. The conical element

dimensions have been selected to provide approximately the same surface area as the comparable cylindrical element so that the pressure drop through the filter media is the same and, therefore, the effect on the annular velocity and pressure drop through the open (base) end cap opening by the conical element configuration is shown:

	Conventional	Conical	Conventional	Conical
OD(top)	2.75"	1.5"	6"	4"
OD(base)	2.75"	4"	6"	8"
Length	30"	30"	36"	36"
ID(base)	1.75"	3"	4"	6"
Vessel ID	4"	4"	8"	8"
Surface Area	1.80 ft ²	1.80ft ²	4.71ft ²	4.72ft ²
Flow(ACFM)	27.6	27.6	91.5	91.5
Face Vel.(fpm)	15.3	15.3	19.4	19.4
Annular Vel (fps)	10	6.13	10	5.83
Base ID Δ P (psid)	0.24	0.03	0.1	0.02

In both cases, the conical element provides lower annular velocities than the cylindrical element (6.13 vs. 10 and 5.83 vs. 10) at the same flow rate and face velocity. In addition, the pressure drop through the end cap (Base ID) is substantially lower (0.03 vs. 0.24 and 0.02 vs. 0.10).

Example 2

A benefit of the improved conical coalescing filter element design is the ability to flow more gas in a given diameter filter vessel. In Example 2, the length of the conical element has been increased to provide increased surface area compared to the referenced cylindrical element in order to flow more gas through the media at the

same pressure drop (related to face velocity) and annular velocity in the vessel.

	Conventional	Conical	Conventional	Conical
5				
OD(top)	2.75"	1.5"	6"	4"
OD(base)	2.75"	4"	6"	8"
Length	30"	49"	36"	62"
ID(base)	1.75"	3"	4"	6"
Vessel ID	4"	4"	8"	8"
10				
Surface Area	1.80 ft ²	2.93ft ²	4.71ft ²	8.08ft ²
Flow(ACFM)	27.6	45	91.5	157
Face Vel.(fpm)	15.3	15.3	19.4	19.4
Annular Vel	10	10	10	10
(fps)				
15				
Base ID Δ P	0.24	0.08	0.1	0.06

In both cases, the conical element provides higher flow rates than the cylindrical element at the same annular velocity (45 vs. 27.6 and 157 vs. 91.5). In addition, the pressure drop through the end (Base ID) is substantially lower (0.08 psid vs. 0.24 psid and 0.06 psid vs. 0.1 psid).

Referring now to Fig. 1, there is shown a diagrammatic view of a typical prior art filter construction wherein a hollow cylindrical filter element 20 is displaced within a cylindrical housing 21. The fluid or gas to be filtered is introduced at the inlet 22 and proceeds from the interior of the filter 20 to the exterior thereof and travels between filter element 20 and the cylindrical housing 21 until it exits the filter housing. Since the annular velocity V_a can be expressed as the quotient of the flow Q divided by the area A between the filter element 20 and the filter housing 21, it can be seen that as the flow increases from 0% at the bottom of the filter element 20, to 100% at the top of the filter element, with the area constant, the velocity must

be increasing. As discussed above, if the velocity becomes too great, the coalesced liquid droplets, which are normally travelling toward the bottom of the filter element 20, will be reentrained in the air stream, and the efficiency will be reduced.

In contrast, Fig. 2 shows a diagrammatic view of the conical coalescing element 25 of the present invention mounted in the same filter housing 21. Again, air enters through the inlet 22 and travels upwardly. This time, because the area between the filter element 25 and filter housing 21 is increasing, by proper filter design the annular velocity can be held constant, substantially constant, or be made to decrease, depending on the particular parameters chosen by the filter designer.

Referring now to Fig. 3, there is shown a typical T-type filter assembly 30. The filter assembly has what is known in the art as a T-shaped head 35 having an inlet 36 including a central opening 37. The filter head also has an outlet 38 communicating with annular space 39. Together the inlet 36 and the outlet 38 comprise means for introducing the fluid to be filtered to the interior of the filter assembly. A threaded portion 40 is provided on the lower end of the head 35, to which a retaining ring 41 may be threadably attached. Held by the retaining ring 41 is a filter bowl 42 having a rim 43 which is pressed against an O-ring 45 mounted in a suitable groove 46 in the head 35. It can be seen that the combination of the head 35, the retaining ring 41 and the O-ring define a sealed interior space 46. The inlet 36 and the outlet 38 sealingly communicate with the interior space 46.

A filter retaining means 47 is provided centrally of the filter head 35 and is contained within the sealed interior space 46.

5 A conical filter element 50 having a lower end 50A and an upper end 50B, is sealingly mounted between end cap 51 which is threadably attached to retaining means 47, and the annular sealing surface 48 provided about the central opening 37. In this embodiment of the invention, the annular sealing surface 48 is provided integrally with the
10 filter head 35, and replaces an upper end cap sometimes found in T-type filter housings.

In this manner, the conical filter element 50 has its ends 50A and 50B substantially closed between a pair of closure members, in this case annular sealing surface 48
15 and end cap 51, and is mounted inside a suitable filter housing having inlet means sealingly communicating with the interior of said filter, and outlet means communicating with the atmosphere.

Referring now to Figs. 4 and 5, there is shown a high
20 efficiency, multiple element, coalescing filter such as that manufactured by Applicant's assignee, but modified to accept the conical coalescing filter element of the present invention. In this embodiment, the multi-element filter assembly 60 has a filter housing 61 having an inlet
25 62 and an outlet 63. Interposed between the inlet 62 and outlet 63 is a tube sheet 64 having a plurality of openings therein communicating with risers 65 having integral end cap portions 65A thereon, to which are mounted a plurality of elongated conical filter elements
30 67. Depending upon the design considerations as hereinbefore discussed, the elongated conical filter elements 67 may be true cones having a rounded apex (not

shown), or they may be as shown having upper and lower sealing surfaces (67A, 67B) and sealed between the sealing surfaces 65A of the risers and the end cap assembly 68 held in place by the retaining rod 69.

5 Large contaminants and liquid slugs entering through the inlet 62 collect in a lower sump 72 and are drained through the lower drain 73. The remaining liquid aerosols are coalesced away from the gas stream and drained into the upper sump 70 away from the flow of the gas stream by
10 the coalescing elements 67. The upper sump is drained as needed through the upper drain 71.

 Thus, by carefully studying the problems present with conventional coalescing filter elements, I have developed a novel conical coalescing filter element and various
15 filter assemblies which can be used in conventional filter assemblies for improved performance.

I CLAIM:

1. A porous filter element of conical shape formed
of randomly orientated glass fibers which flows from the
5 inside to the outside.

2. The filter defined in claim 1, and having an
upper annular sealing surface and a lower annular sealing
surface.

10

3. The filter defined in claim 2, and further
including:

a) at least one layer of a suitable thin sheet
material wrapped around said porous filter element,
15 and being in intimate contact therewith.

4. The filter defined in claim 3, and further
including a seamless outer support structure of sufficient
rigidity to radially support said porous filter tube and
20 said suitable thin sheet material and having an inside
diameter slightly smaller than the outside diameter of the
combination of the porous filter tube and said outer layer
of sheet material and completely surrounding said
combination.

5. A filter including, in combination:

a) a seamless inner support structure of an conical configuration,

5 b) an inner layer of suitable sheet material wrapped around said tubular support structure,

c) a porous filter element formed of randomly orientated glass fibers and being of conical shape,

10 d) at least one outer layer of a suitable thin sheet material wrapped about said filter tube and being in intimate contact therewith,

15 e) a seamless outer support structure of conical configuration and being of sufficient rigidity to radially support said porous filter tube and said suitable thin sheet material and having an inside diameter slightly smaller than the outside diameter of the combination of said inner tubular support structure, said inner layer of said suitable sheet material, said porous filter tube, and said outer layer of suitable sheet material and completely
20 surrounding said combination.

6. A filter assembly including:

a) a conical porous filter element formed of randomly oriented glass fibers and having an upper flat annular flat sealing surface and a lower annular flat sealing surface, and

b) means for introducing the fluid to be filtered to the interior of said filter in such a manner that such fluid will flow through the conical coalescing filter element, from in to out, wherein said filter element has its ends substantially closed by a pair of closure members, and is mounted inside a suitable filter housing having inlet means sealingly communicating with the interior of said filter.

7. A filter assembly comprising a conical coalescing filter element as described in either one of claims 1, 4 or 5, and including means for introducing the fluid to be filtered to the interior of said filter at the inside of the innermost filter layer in such a manner that such fluid will flow through the remaining layers of said filter from inside to outside, and wherein said conical coalescing filter element has its ends substantially closed by a pair of closure members, and mounted inside a suitable filter housing having inlet means sealingly communicating with the interior of said filter, and outlet means communicating with the atmosphere.

8. The porous filter element described in claim 1, wherein said filter element is manufactured from a filter media originally in a flat sheet form.

9. The porous filter element described in claim 8, wherein said filter media is pleated during the manufacturing process.

5 10. A multiple element coalescing filter assembly including, in combination:

 a) a filter housing having an inlet and an outlet,

 b) a tube sheet, having a plurality of
10 openings interposed between said inlet and outlet,

 c) a plurality of risers sealingly connected to said openings and said tube sheets and having integral filter sealing surfaces at the upper ends thereof,

15 d) a plurality of elongated conical filtering elements mounted to said risers,

 e) an end cap assembly applying pressure axially to said elongated conical filtering elements to seal said elements between said integral sealing
20 surfaces provided on said risers and said end cap assemblies,

 f) a lower sump provided immediately above said tube sheet,

 g) an upper drain in fluid communication with
25 said upper sump,

 h) a lower sump provided below the inlet of said filter housing, and

 i) a lower drain communicating with said lower sump.

30

11. A porous coalescing filter element of conical shape which flows from the inside to the outside.

12. The coalescing filter element described in claim 11, wherein the filter media is made of randomly oriented fibers.

5 13. The coalescing filter element described in claim 11, wherein the element is made from borosilicate glass.

10 14. The coalescing filter element described in claim 11, wherein the element is made from polypropylene.

15 15. The coalescing filter element described in claim 11, wherein the element is made from polyethylene.

16. The coalescing filter element described in claim 11, wherein the element is made from polyester.

20 17. The coalescing filter element described in claim 11, wherein the element is made from nylon.

25 18. The coalescing filter element described in claim 11, wherein the element is made from polytetrafluoroethylene.

19. The coalescing filter element described in claim 11, wherein the element is made from ceramic.

30 20. The coalescing filter element described in claim 11, wherein the element is made from cellulose.

21. The coalescing filter element described in claim 11, wherein the element is made from steel.

22. The coalescing filter element described in claim 5 11, wherein the element is made from stainless steel.

23. The coalescing filter element described in claim 11, wherein the element is made from inconel.

10 24. The coalescing filter element described in claim 11, wherein the element is made from monel.

25. The coalescing filter element described in claim 11, wherein the element is made from copper.

15

26. The coalescing filter element described in claim 11, and having a sealing surface on one end.

27. The coalescing filter element described in claim 20 11, and having a sealing surface on both ends.

28. The coalescing filter element defined in claim 27, and further including at least one layer of a suitable thin sheet material wrapped around said conical porous 25 filter element and being in intimate contact therewith.

29. The coalescing filter defined in claim 26, and further including at least one layer of a suitable porous sheet material wrapped around said conical porous filter 30 element and being in intimate contact therewith, said porous sheet material having larger pores than the filter media.

30. The coalescing filter element described in claim 26, and further including an outer support structure of sufficient rigidity to radially support said porous filter element and said suitable sheet material and having an
5 inside diameter substantially the same or slightly smaller than the outside diameter of the combination of the porous filter element and said outer layer of sheet material and completely surrounding said combination.

10 31. The coalescing filter element described in claim 27, and further including an outer support structure of sufficient rigidity to radially support said porous filter element and said suitable sheet material and having an
15 inside diameter substantially the same or slightly smaller than the outside diameter of the combination of the porous filter element and said outer layer of sheet material and completely surrounding said combination.

20 32. The coalescing filter element described in claim 28, and further including an outer support structure of sufficient rigidity to radially support said porous filter element and said suitable sheet material and having an
25 inside diameter substantially the same or slightly smaller than the outside diameter of the combination of the porous filter element and said outer layer of sheet material and completely surrounding said combination.

33. The coalescing filter element described in claim 29, and further including an outer support structure of sufficient rigidity to radially support said porous filter element and said suitable sheet material and having an inside diameter substantially the same or slightly smaller than the outside diameter of the combination of the porous filter element and said outer layer of sheet material and completely surrounding said combination.

34. A coalescing filter element including, in combination:

a) an inner support structure of a conical configuration,

b) an inner layer of suitable sheet material wrapped around said inner support structure,

c) a porous coalescing filter element formed of randomly orientated fibers and being of conical shape,

d) at least one outer layer of a suitable thin sheet material wrapped about said filter element and being in intimate contact therewith,

e) an outer support structure of conical configuration and being of sufficient rigidity to radially support said porous filter element and said suitable thin sheet material and having an inside diameter substantially the same or slightly smaller than the outside diameter of the combination of said inner conical support structure, said inner layer of said suitable sheet material, said porous filter element, and said outer layer of suitable sheet material and completely surrounding said combination.

35. A coalescing filter assembly including:

a) a conical porous filter element having an upper annular flat sealing surface and a lower annular flat sealing surface, and

5 b) means for introducing the fluid to be filtered to the interior of said filter in such a manner that such fluid will flow through the conical coalescing filter element from in-to-out, wherein said filter element has its ends substantially closed by a pair of closure
10 members, and is mounted inside a suitable filter housing having inlet means sealingly communicating with the interior of said filter, and outlet means communicating with local atmosphere or inside chamber of said filter.

15 36. A coalescing filter assembly comprising a conical coalescing filter element as described in and one of claims 11, 12, or 26-31, and including means for introducing the fluid to be filtered to the interior of
20 said filter element at the inside of the innermost filter layer in such a manner that such fluid will flow through the remaining layers of said filter from inside to outside, and wherein said conical coalescing element has its ends substantially closed by a pair of closure
25 members, and mounted inside a suitable filter housing having inlet means sealingly communicating with the interior of said filter element and outlet means communicating with the local atmosphere.

37. A multiple element coalescing filter assembly including, in combination:

- a) a filter housing having an inlet and an outlet,
- b) a tube sheet, having a plurality of openings
5 interposed between said inlet and outlet,
- c) a plurality of elongated conical filtering elements mounted to said openings, and
- d) having inlet means sealingly communicating with the interior of said filter elements and outlet means
10 communicating with the local atmosphere.

38. A multiple element coalescing filter assembly including, in combination:

- a) a filter housing having an inlet and an outlet,
- 15 b) a tube sheet, having a plurality of openings interposed between said inlet and outlet,
- c) a plurality of risers sealingly connected to said openings and said tube sheets and having integral filter sealing surfaces at the upper ends thereof,
- 20 d) a plurality of elongated conical filtering elements mounted to said risers,
- e) an end cap assembly applying pressure axially to said elongated conical filter elements to seal said elements between said integral sealing surfaces provided
25 on said risers and said end cap assemblies,
- f) a lower sump provided immediately above said tube sheet to collect coalesced liquids,
- g) a drain in fluid communication with said sump to drain collected liquids.

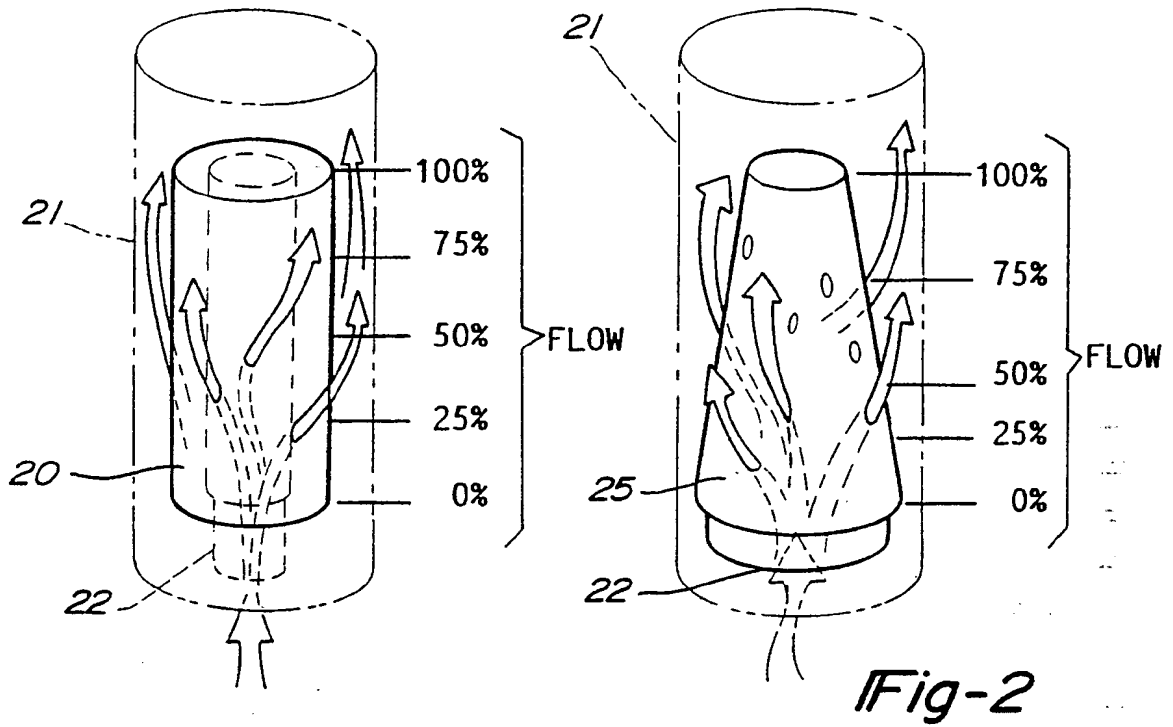
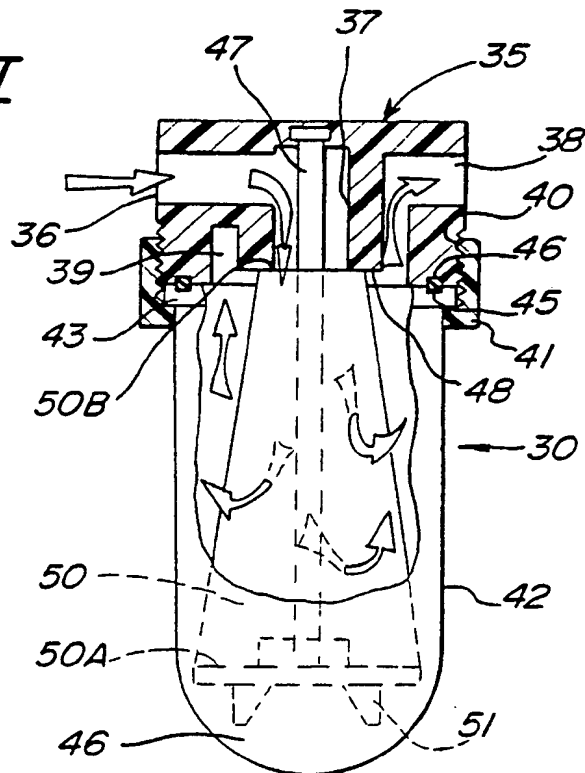


Fig-1
PRIOR ART

Fig-3



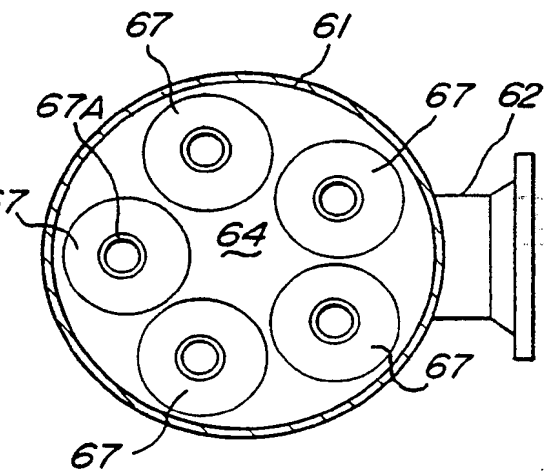
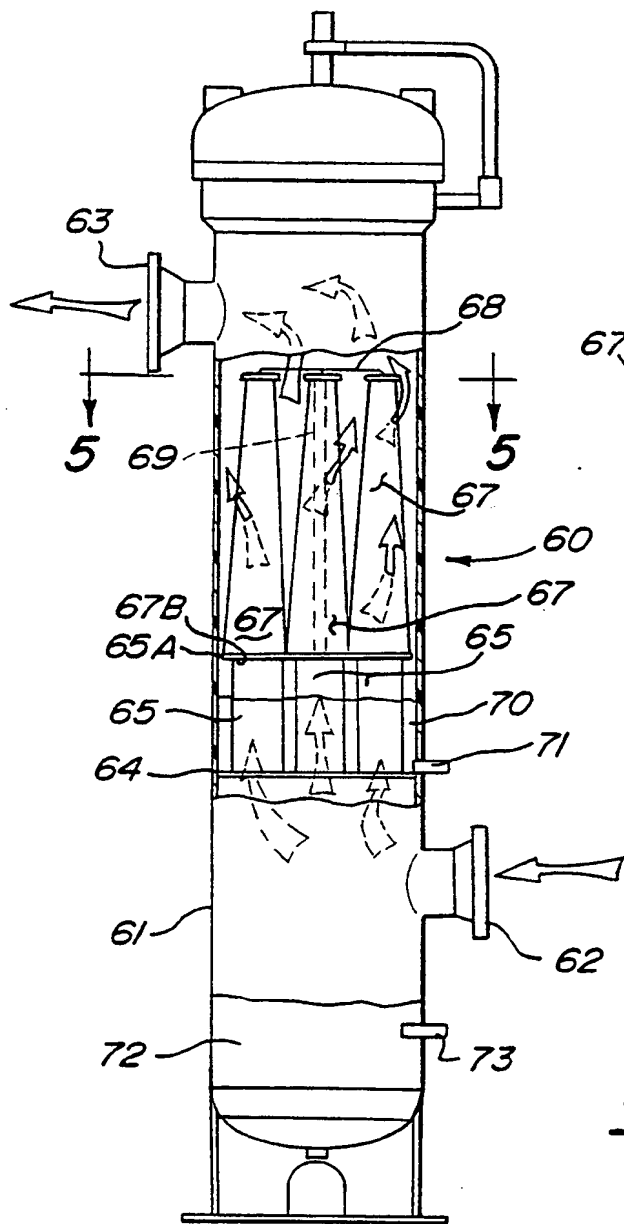


Fig-5

Fig-4

INTERNATIONAL SEARCH REPORT

PCT/US92/07383

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B01D 29/88

US CL :210/317,337,497.3

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 210/315,338,493.1,497.01

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<u>X</u> Y	US,A, 4,309,289 (Head) 05 January 1982 See column 3, lines 44-47.	<u>11</u> 7/1,12,14, 15-20,35-36
<u>Y</u> A	US,A 4,038,194(Luceyk et al.) 26 July 1977. See entire document.	<u>1-2,6,8-9,26-27</u> 4,7/4,5,7/5, 13,21-25,30-34
Y	US,A, 2,864,505 (Kasten) 16 December 1958 See col. 2, lines 19-29.	3,28-29
Y	US,A, 4,892,667 (Parker, III et al.) 09 January 1990. See entire document.	10, 37-38

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

26 JANUARY 1993

Date of mailing of the international search report

08 FEB 1993

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